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ID-213

Kentucky Compost-Bedded Pack Barn Project

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Background

Kentucky dairy producers are adopting compost-bedded pack barns (CBP) as dairy cattle housing at a rapid rate. When properly managed, as an alternative dairy housing system, CBPs may decrease somatic cell count (SCC), increase production, and reduce lameness. Because the system is relatively new, however, many questions remain regarding best management practices and key factors for success.

University of Kentucky dairy scientists and agricultural engineers conducted a comprehensive observational study of Kentucky CBPs from October 2010 to March 2011. The goal of this research was to determine key management concepts that determine success or failure in the compost-bedded pack system. The findings of this research may be used by current and future CBP managers.

Kentucky county agricultural extension agents and Kentucky Dairy Development Council (KDDC) consultants identified Kentucky producers operating compost-bedded pack systems. If a farmer described the barn as a CBP but the pack was rarely or never stirred, the barn was not included in data analysis or reports. Forty-three farms participated in the study, with some farms managing multiple compost packs, resulting in 51 total compost packs. This report is a summary of study results. (Note: Throughout the paper, the abbreviation "n" denotes the number of producers who selected a particular response category.)

Herd Characteristics

The number of cows housed on the pack ranged from 19 to 184 with an average of 90 cows (n = 47). The primary breeds were Holstein (n = 29), Jersey (n = 3), and mixed (n = 9). Producer-reported average daily milk production per cow was 60 pounds (n = 39), ranging from 45 to 79 pounds, with average fat and protein contents of 3.88 percent (n = 35) and 3.25 percent (n = 6), respectively. Producers participating in the Dairy Herd Information Association (DHIA) had an average daily milk production of 64 pounds (n = 32) and an average milk protein content of 3.19 percent. Average producer-reported that SCC for all herds was 247,000 cells/mL (n = 38), ranging from 100,000 to 428,000 cells per milliliter. Herds utilizing DHIA had a SCC average of 318,000 cells per milliliter (n = 15). The main culling criteria were reproduction (n = 32), feet and legs (n = 8), and mastitis (n = 6). Main culling reasons, according to DHIA, were death (6.89%), reproduction (4.80%), and production (4.17%).

Producer Responses

Producers were asked:

- Are you satisfied with your barn?
- What are the benefits of the CBP?
- What changes would you make in your facility?
- What recommendations can you make to other farmers building new facilities or not having success with their current facilities?
- What lessons did you learn throughout the process?

Of the 43 producers visited, 42 responded that they were satisfied with their CBP, and only one stated that he was sometimes satisfied.

Benefits

The most frequently cited benefits of the CBP include increased cow comfort compared to freestalls (n = 28), increased cow cleanliness (n = 14), low maintenance (n = 10), works well for heifers and lame, fresh, problem, and old cows (n = 10), and allows a natural resting position with no freestalls (n = 9). Other benefits are cited in Table 1.

Table 1. Benefits of CBPs

Benefit	Producer Responses
Improved cow comfort	28
Increased cow cleanliness	14
Good for heifers, lame, fresh, problem, and old cows	10
Low maintenance	
Allows natural resting position (no stalls)	9
Proximity to parlor (compared to pasture)	8
Improved feet and legs	
Decreased SCC	6
Increased heat detection	
Ease of manure handling	3
Increased longevity	
Increased production	
Increased dry matter intake (compared to pasture)	
Minimizes time standing on concrete	2
Fewer leg and teat injuries	

Other benefits cited: Reduced bedding cost, cleaner pasture, investment cost, less odor, fewer flies, and manure value.

Changes

When asked what they would change about their CBP, producers frequently cited (n = 15) the size, or capacity, of the pack. Increasing natural ventilation or sidewall height (n = 12), adding a retaining wall around the perimeter of the barn (n = 6), adding curtains during the winter (n = 5), and building the barn without posts in the pack (n = 4) were also aspects that producers would change about their current facilities (Table 2).

Table 2. Recommended facility changes

Change	Producer Responses
Increase size or capacity of the barn	15
Higher sidewalls and improved ventilation	12
Add a retaining wall	6
Add Curtains	5
More fans	
Larger ridge vent	
No posts in pack	4
Increase number or change location of waterers	
Change location or increase length of feed bunk	
Increase length of overhang or eaves	3

Other recommended facility changes: Add close-up cow pen, change tilling equipment, add rubber flooring in alleys, expand concrete area in the feed alley, add sprinklers, and position lagoon nearby.

Lessons

Supply of bedding is one of the biggest concerns of many producers. Shavings are used in industries other than dairy and are becoming more difficult to obtain. Eleven producers recommended that those considering building a CBP should secure a bedding supply first. Recommendations also included stirring the pack two or more times per day (n = 9) and using kiln-dried shavings (n = 6). Producers also suggested avoiding the use of straw, wheat straw, corn fodder, soybean fodder, or pine shavings/sawdust as a bedding material (n = 6) and maintaining the pack by keeping moisture low (n = 5) (Table 3).

Compost Bed Temperature and Moisture Measurements

Another objective of this study was to assess the success of the composting process through a snapshot observation of the barn at the time of the visit. A compost bed is influenced by many factors that occur over the days and weeks prior to an on-site visit, including weather, cow stocking density, cow access to pastures, bedding usage, type of bedding material, bed stirring strategy, and tillage implement used. Long-term factors such as barn structure, air ventilation/circulation, presence of sidewall curtains, and manager understanding of the composting principles also affect the bed. The measures of success are indicated by the temperature and moisture content of the compost bedding. Each barn compost bed resting area was divided into nine equal areas. At the center of each area, the temperature of the compost was measured at an eight-inch depth. In addition, a sample of the compost was collected from the four-inch depth for determining the moisture content. The air temperature outside the barn was also measured.

The collected data is summarized in the following sections using primarily graphical formats to visually present (1) trends that were found over the collection period, (2) the range of stocking density, and (3) bed moisture content achieved. Each graph has a trend line that is significant except where noted. The scattered data reflects the many differences found in barn structure and management. Forty-eight compost beds were sampled, 19 in the fall and 29 during the winter.

Compost Bed Moisture Trend

During the project period, a distinct change in weather on 11/17/2010 marked the division between fall and winter. Figure 1 depicts the fall/winter distinction clearly. Note that as the outside temperatures decreased, the bedding moisture increased considerably. In the winter, keeping compost packs dry is more difficult because of reduced drying rates; thus, more bedding is needed to maintain a dry resting surface for cows.

Table 3. General recommendations

Lesson	Producer Responses
Secure a bedding supply	11
Stir two times per day or more frequently	9
Do not use straw, wheat straw, corn fodder, bean fodder, or pine	6
Use kiln-dried shavings	
Keep pack maintained and moisture low	5
Maintain a minimum of 100 sq. ft. per cow	
Add bedding frequently	4
Build the barn large	
Tour other barns	3
Add curtains	
Use a designated tractor for stirring	
Do not start pack during winter	

Other building recommendations: Build the barn with correct orientation, long overhang, high sidewalls, ventilation and fans, consider cow flow in building process, steel structure for durability, don't use short cuts, put gates by the feed alley, avoid congregation, no posts on the pack, two-gate system for entrances, use fans in winter to dry pack, concrete heavy use areas, do not put waterers on the pack, consider existing manure handling when designing barn, build with flexibility to convert to freestalls, more entrances to pack to avoid wet areas, put feed bunk in barn, feeding in the barn is more challenging, do not try to save money, more production when using the pack, learn through doing

Stirring recommendations: Wide sweeps on cultivator for more turning of compost, use a cultivator to stir, does not help to stir 18 inches deep, stirring depth is important in compost success, stir in early afternoon in winter to reduce heat loss, use a rototiller in cold weather

Shaving recommendations: Need fine and coarse wood particles, do not use green sawdust, soy stubble can work in correct ration, pay for better shavings, do not bed off often in summer or will become too dry, white oak shaving can work as bedding material, wood shavings work best for bedding material, dusty bedding can cause respiratory problems

Compost Bed Temperature Trend

The importance of the bedding moisture content is reflected in the bedding temperature (8" depth). Maximum bed temperatures tend to be achieved when the bed moisture content is between 40 and 60 percent because at that moisture level sufficient water is present for aerobic bacteria to achieve their highest activity and produce maximum heat. Figure 2 demonstrates the bed temperature trend. The temperatures have a wide scatter, but the seasonal averages are significantly different; in fall the average bed temperature was 104° F while in winter the temperature was 89° F (see Figure 17). One can observe that some of the highest (136° F) and lowest (56° F) temperatures were achieved in the winter. The factors associated with the highest winter temperatures were (1) thorough, deep bed mixing (10-12") to achieve maximum oxygen for heat production, (2) moisture contents between 40 and 60 percent for maximum bacterial activity, and (3) windward sidewall curtains to reduce compost bed heat loss to the atmosphere when cold winter winds are blowing.

Bedding Type

Producers often ask whether green sawdust (high-moisture sawdust from sawing green wood) is harmful or beneficial to the composting bed. The primary difference between green sawdust and kiln-dried sawdust is that green sawdust will not absorb as much water as kiln-dried sawdust; consequently, more green sawdust must be used to achieve the same compost bed moisture content as kiln-dried sawdust. Figure 2 illustrates that throughout the project time, in kiln-dried sawdust (circles), green sawdust (diamonds), and mixtures of both (triangles), no trends were found. Table 4 breaks down the usage of the different bedding materials, showing that more than half of the barns in the study were using kiln-dried sawdust. Caution must exercised with green sawdust as it has a reputation for leading to *Klebsiella* mastitis in freestall barns.

Table 4. Bedding material

Bedding material	Producers (%)
Kiln-dried	53
Green	31
Mix	16

The effects of different bedding types on compost bed temperatures and moisture contents by fall and winter seasons are found in Figure 3. Although the averages show some difference within a season, they were not significantly different.

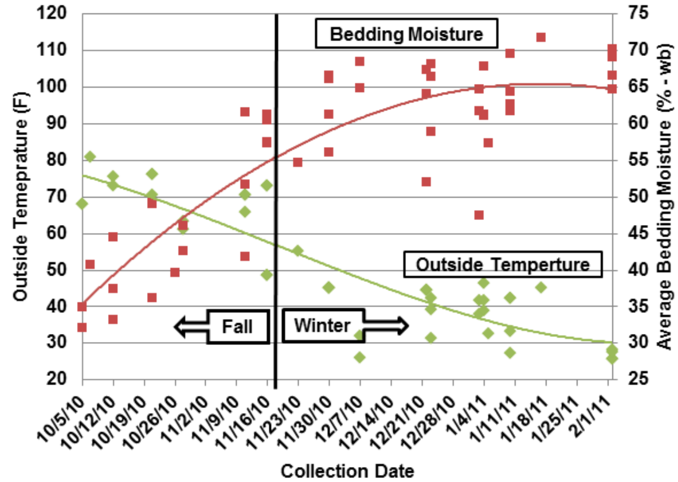

Figure 1. Average bed moisture content and outside air temperature over collection period

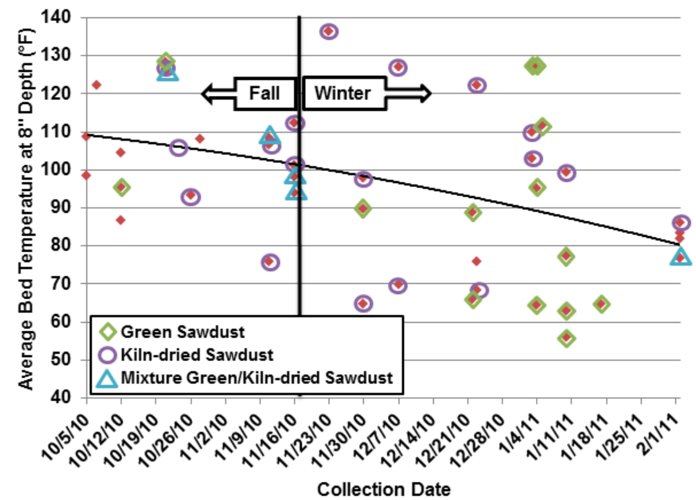

Figure 2. Average bed temperature and bedding material used during the sampling period

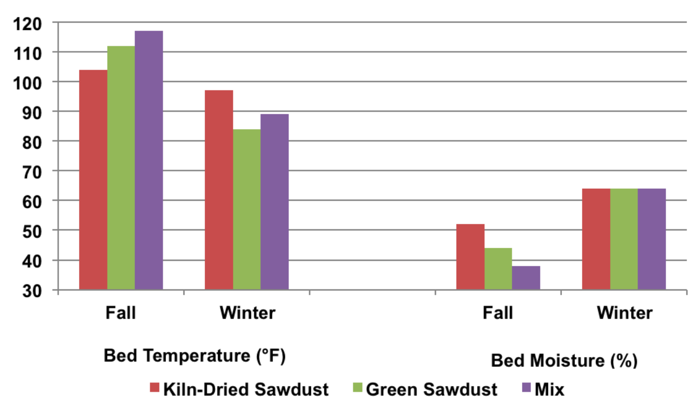

Figure 3. Seasonal effects of bedding source on compost bed moisture and temperature

Compost Bed Moisture Content Effects on Compost Bed Temperature

The moisture content range for maximum aerobic microorganism heat production is 40 to 60 percent. The relationship between average bed moisture content on the average compost bed temperature at eight-inch depth for fall season (solid diamonds) and winter season (solid squares) is illustrated in Figure 4. The figure shows that the maximum temperatures occurred in the optimal moisture content range of 45 to 55 percent. The recommended management range is also shown (40-60%). The data in Figure 4 demonstrate that some beds had high temperatures outside the recommended moisture range. The data in Figure 4 is summarized in Table 5 to show bed temperature averages and temperature ranges broken down by moisture range and season.

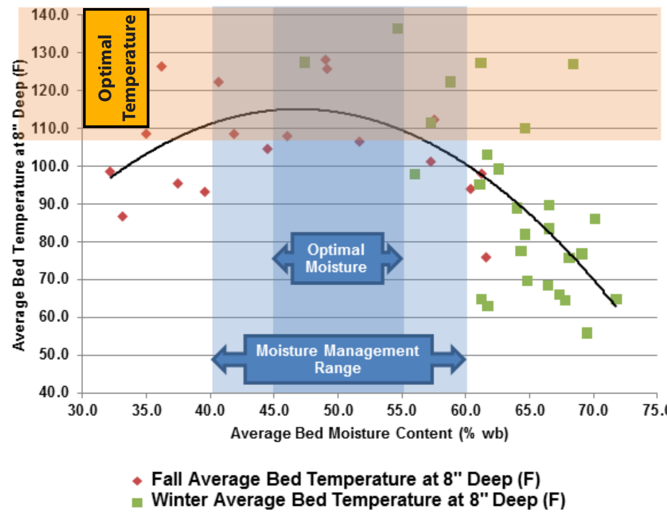

Figure 4. Effects of average bed moisture content on average bed temperature

Cow Stocking Density on Compost-Bedded Pack

Cow stocking density (ft.^{2}/cow) on the composted pack is a key barn management element. Excessive stocking density leads to a high bedding moisture content that inhibits composting, particularly during the winter season. Inadequate stocking density leads to bedding with insufficient moisture to compost. That condition occurs mostly in prolonged warm/hot weather when bed drying rates are higher than in winter. Summer periods of dry compost are not critical to compost bed success, but management must recognize that as the cooler fall weather season begins proper moisture and cow stocking density become important management criteria to achieve a bed moisture range that supports the composting process. Cow stocking density of the CBPs in Kentucky is summarized in the left half of Figure 5. Based on cow numbers reported by the dairyman, nearly one quarter of the barns (21%) are populated at the recommended density of 100 to 110 feet squared per cow, 18 percent of the barns are populated to a slightly higher density (90-100 ft.^{2}/cow), and 23 percent are populated at a lower density (110-130 ft.^{2}/cow). However, stocking densities based solely on cow numbers do not take into account the actual production of moisture by the cow through urine and feces. Larger cows and cows producing larger amounts of milk daily will produce more moisture because they consume more feed and water. To account for those factors, an adjusted stocking density was calculated. With that adjustment (right side of Figure 5), there is a considerable shift in the frequency distribution to more barns with higher densities. Under the adjusted animal density, the second highest frequency of cow stocking density is 60 to 80 feet squared per cow (20%), which is too high for a composted pack, and the number of farms at the recommended cow stocking density (100 to 110 ft.^{2}/cow) falls from 21 percent to 15 percent.

Table 5. Moisture and temperature (°F) for 8-inch-deep compost beds

	# Barns	Bed temp. (%)	Temp. range
All beds			
Fall	19	104	76 - 128
Winter	29	89	56 - 136
All	48	95	56 - 136
Moisture bontent <35%			
Fall	3	98	87 - 109
Winter	0	--	--
All	3	98	97 - 109
Moisture bontent 35 - 45%			
Fall	7	109	93 - 126
Winter	0	--	--
All	7	109	93 - 126
Moisture bontent 45 - 55%			
Fall	5	113	95 - 128
Winter	3	111	68 - 136
All	8	108	68 - 136
Moisture content 55 - 65%			
Fall	6	95	76 - 112
Winter	13	95	63 - 127
All	19	95	63 - 127
Moisture content >65%			
Fall	0	--	--
Winter	14	79	56 - 127
All	14	79	56 - 127

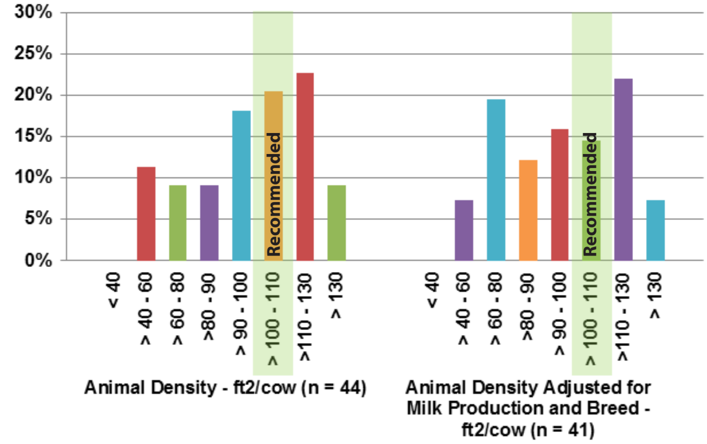

Figure 5. Cow stocking density or area per cow (n = 44)

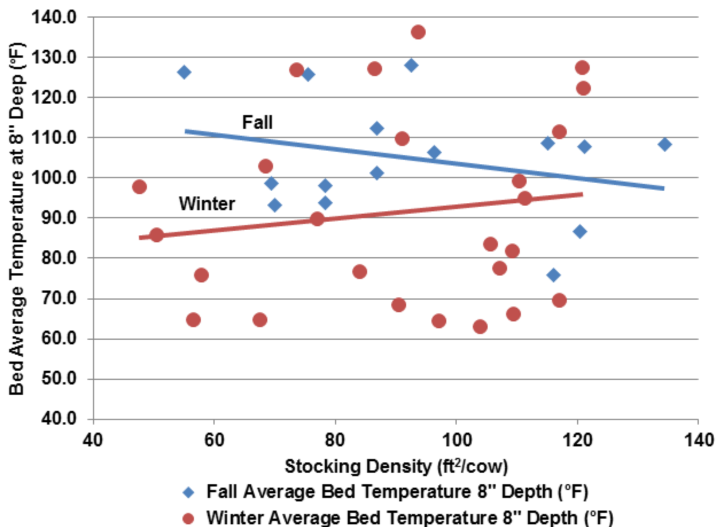

Figure 6. Effect of adjusted stocking density on compost bed temperature

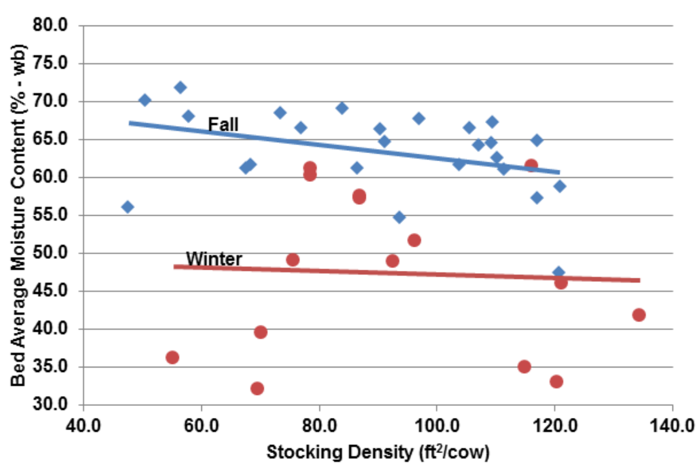

Figure 7. Adjusted stocking density effect on compost bed moisture content.

Cow Stocking Density Effects on Compost Bed Average Temperature and Moisture Content

The cow herd size, as reported by the dairymen, was adjusted for breed size and milk production. The adjusted cow stocking density effect on average compost bed temperature is presented in Figure 6. The temperatures were divided between the fall and winter seasons. The trend lines indicate, as would be expected, that the fall compost bed temperature decreases as the stocking density is reduced. Less net water accumulates in the compost bed during the higher drying rates that are found in the fall. The bed moisture content becomes lower and less heat generated as it falls below the optimum moisture range for high microorganism activity. The opposite trend is found in the winter season when drying rates are lower. The lower stocking density leads to less moisture added to the compost bed allowing the winter drying rate to lower the moisture content. The bed moisture content becomes lower and will enter the optimum moisture region of maximum heat generation rate of the microorganisms. The effects of the stocking density on the compost bed moisture content are shown in Figure 7. The trend lines for both the fall and winter seasons indicate lower compost bed moisture contents with lower stocking density. The trend lines in Figure 7 are significant.

Lameness and Hygiene

Lameness and hygiene scores were collected for at least 50 cows per pack, unless there were fewer than 50 cows in the herd, and then every cow was scored. Cows were randomly selected to be scored based on tag number (i.e. even tag number, multiples of 3). Farms using the compost-bedded pack as special needs housing were not scored for locomotion since they were likely on the pack due to lameness. Hygiene scores for special needs cows were also excluded since the CBP was not the only housing system influencing their hygiene. Forty-four compost-bedded packs were used in assessing locomotion and hygiene.

Cows on the pack had an average locomotion score of 1.50 (n = 2,258, 1 = normal, 5 = severely lame). A research study in Minnesota found that the average locomotion score of cows housed in freestalls was 2.08 (n = 5,626). Providing a soft walking surface for cows can impact the stress on the joints and legs, especially when compared to concrete.

The average hygiene score of cows was 2.21 (n = 2,260, 1 = clean, 4 = dirty). Allowing cows to rest on a clean, dry environment can greatly influence the hygiene, and thus, the bacterial load at the teat end. The heat generated by the composting process coupled with natural and forced ventilation helps to dry the top layer of compost, providing the dry surface for cows. This in turn reduces the amount of material that may stick to the cow when she stands, decreasing the organic material and bacterial load on the body and, more importantly, the udder.

Bacterial Concentrations

Conventional bedded packs typically carry the stigma of having large bacterial loads that can later lead to increased incidence of mastitis. This stigma remains with compost-bedded packs as well. Researchers hypothesize that the heat generated by the composting action will actually slow bacterial growth and kill existing bacteria, meaning that compost-bedded packs may have lower bacterial loads than those of a conventional bedded packs. However, little research has been done to prove or disprove this hypothesis.

Mastitis-causing bacteria can be classified in two groups: environmental and contagious. Environmental bacteria are picked up from the cow's surroundings, such as bedding, pasture, and ponds. Contagious bacteria are transferred from cow to cow in the parlor through improper milking procedures or malfunctioning equipment. Even the cleanest and highest-producing farms have bacteria, but proper milking procedures and management practices in the parlor can help keep the incidence of infection low. Bacteria counts are reported in colony-forming units per gram (cfu/g), the number of viable bacteria cells in a gram of material.

Coliforms are environmental bacteria associated with fecal matter. *Escherichia coli* (*E. coli*) is one type of coliform bacteria that causes environmental mastitis along with *Klebsiella* and *Enterobacter*. Staphylococcal species can be contagious or environmental bacteria. *Staphylococcus aureus* is a contagious strain of this bacterium that is difficult to eradicate from the herd. Coagulase-negative Staphylococcus are considered environmental organisms that often cause subclinical mastitis. Streptococcal species that cause mastitis can be both environmental and contagious. *Streptococcus agalactiae* is a contagious strain that is typically brought into the herd through purchase of new cows and can be eradicated. Non-agalactiae streptococci, including *Streptococcus uberis* and *Streptococcus dysgalactiae,* are both environmental strains of Streptococcus. Bacillus species are an environmental bacterium typically introduced into the udder during treatment, due either to improper sanitation prior to treatment or a contaminated treatment device. *Bacillus cereus* can be a serious and sometimes fatal mastitic pathogen.

Understanding the types of bacteria and their concentration within the compost is important in knowing whether the heat produced by the compost may actually be killing mastitis-causing organisms. Compost samples were collected from nine equally spaced locations throughout the barn. One-half cup was collected from each location, thoroughly mixed together, and stored in a -70°F freezer to be thawed later for analysis of bacterial content. Bacterial content was measured for all species within a bacterium; mastitic pathogens were not isolated. Staphylococcal species were in the largest concentration, with an average of 73,643,617 cfu/g. Bacillus and Streptococcal species had average concentrations of 35,571,840 cfu/g and 29,022,850 cfu/g, respectively. Coliform species were in the lowest average concentrations, 2,625,851 cfu/g, with an average *Escherichia coli* concentration of 1,468,830 cfu/g. Concentrations and ranges are shown in Table 6.

Table 6. Bacterial concentrations (cfu/g) from compost samples (n = 47)

Species	Content (%)	Minimum	Maximum
Coliform	2,625,851	65,000	24,750,000
E. Coli	1,468,830	30,000	17,300,000
Staphylococcal	73,643,617	1,000,000	900,000,000
Streptococcal	29,022,850	236,250	359,500,000
Bacillus	35,571,840	721,500	181,000,000

DHIA Data

Of the 42 farms visited, 31 were enrolled in DHIA. Herds using DHIA were separated into two categories: herds using CBPs as the primary housing and herds using the CBP for a particular group of cows, such as lame, fresh, or young cows. Only herds with data one year before and one year after moving into the CBP were included in the analysis, leaving a total of 12 farms. Averages of DHIA data were taken for the 6 to 12 months after moving into the CBP for the two categories. Improvements in SCC and reproductive performance were observed for herds after moving into the compost barn (Figure 8). The herd averages for the primary housed herds are listed in Table 7 and the herd averages for the herds with special grouped cows are listed in Table 8.

Compost Nutrient Composition

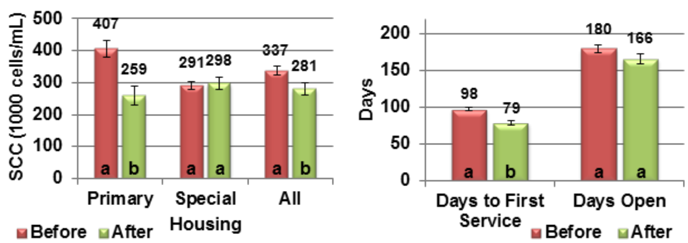

Figure 8. Changes in SCC, days to first service, and days open before and after CPB. Pairs with different subscripts are significantly different ($p<0.05$).

Table 7. DHIA averages during the year after moving into a CPB being used as primary housing

	Average (n = 8)	Minimum	Maximum
Current SCC (cells/mL)	272,000	186,000	325,000
Average daily milk (lb)	68	63	73
Peak milk (lb)	84	86	91
Rolling herd average (lb)	20,178	18,691	22,379

Table 8. DHIA averages for compost barns being used for specially grouped cows during the year after moving into the barn.

	Average (n = 7)	Minimum	Maximum
Current SCC (cells/mL)	265,000	201,000	452,000
Average daily milk (lb)	64	50	78
Peak milk (lb)	84	72	100
Rolling herd average (lb)	20,178	15,803	24,936

Bedding material was collected from nine equal locations throughout the barn and shaken to create a consistent mixture. The University of Kentucky Regulatory Services laboratory processed the samples to determine the nutrient content in the bedding. The averages are shown in Table 9.

Table 9. Bedding material nutrient density, dry matter basis (n = 47)

Nutrient	Average	Minimum	Maximum
	(%)		
Phosphorus	0.4	0.2	0.9
Magnesium	0.5	0.2	1.3
Potassium	1.3	0.4	3.0
Nitrogen	1.7	1.0	2.9
Calcium	2.0	0.6	22.3
Carbon	42.0	21.0	47.0
Moisture	56.0	27.0	70.0
Nutrient	**Average**	**Minimum**	**Maximum**
	(ppm)		
Copper	27.8	7.7	61.9
Zinc	110.4	36.5	217.9
Manganese	222.4	110.8	818.9
Iron	2779.7	471.4	9077.7

Bedding

An average of 1,975 cubic feet of shavings (n = 41) were added to the pack every 19 days (n = 41) in the summer and every 17 days (n = 41) in the winter. Producers used pack moisture as the main indicator to add bedding (n = 26). Visual observation of the cows, such as bedding sticking to cows and dirty cows, was also an indication for adding bedding (n = 12, n = 7, respectively). The producer responses for reasons to add bedding are given in Table 10.

Table 10. Criteria used for adding bedding

Criteria	Producer Responses
Moisture of the pack	26
Bedding sticks to cows	12
Visual observation of the pack	9
Dirty cows	7
Scheduled by calendar	5
Tillage equipment resistence during stirring	3
Compaction or clumps	
Cow lying behavior changes	1
Bedding is available	

Pack Stirring

The pack was stirred 1.6 times per day (n = 42) in the summer and 1.8 times per day (n = 42) in the winter, on average, at an average depth of 9.5 inches (n = 42). Deep stirring incorporates the feces and urine into a larger volume of material, thus providing a better balance of moisture, carbon, and nitrogen in the active compost layer. The deeper stirring introduces more oxygen into the bed, particularly during the winter season, which causes more volume of the bedded pack to generate heat during the cold weather periods. The increased temperature increases the drying rate of the bed, which results in lower compost bed moisture content and reduces the amount of bedding to keep the bed in the moisture management range found in Figure 8. Most producers used a cultivator (n = 33), a few used a rototiller (n = 5), and four producers used both (Figure 9A). Most equipment was pulled on the back of a tractor or skid-steer (n = 36), though some equipment was pushed through the pack (n = 5, Figure 9B).

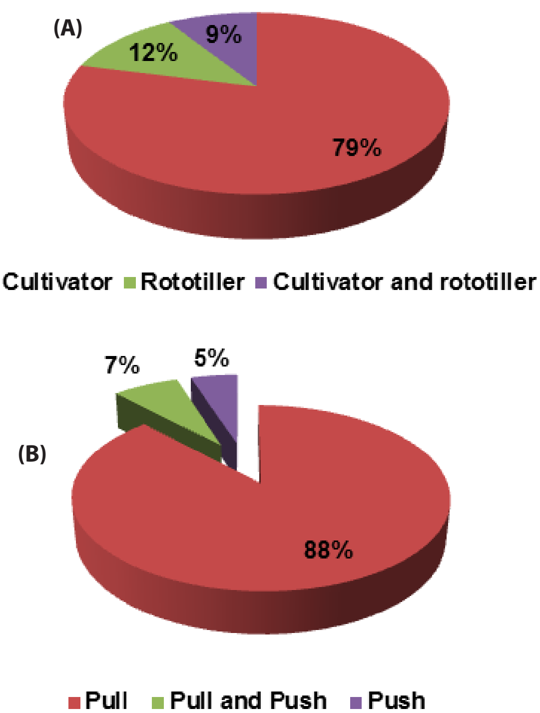

Figure 9. Tillage equipment and method used for pack stirring.

The effect of tillage equipment type can be seen in Figure 10, which illustrates the fraction of bed material that was retained on a sieve with a one-inch screen opening. As seen, the fraction larger than one inch increases with the moisture content of the compost bed. But the use of a rototiller (large diamonds) maintained that fraction below 2 percent. At some of the higher moisture contents, the fraction of material larger than one inch was near 0 percent. Smaller bed particles have a positive impact, supplying more surface area in the compost for compost bedding drying. Smaller particles allow more of the compost to be exposed to oxygen from the stirring process, leading to higher heat generation by the microorganisms. The result, a higher bed drying rate, leads to lower moisture content in the pack and a reduced bedding requirement to maintain proper bed moisture content.

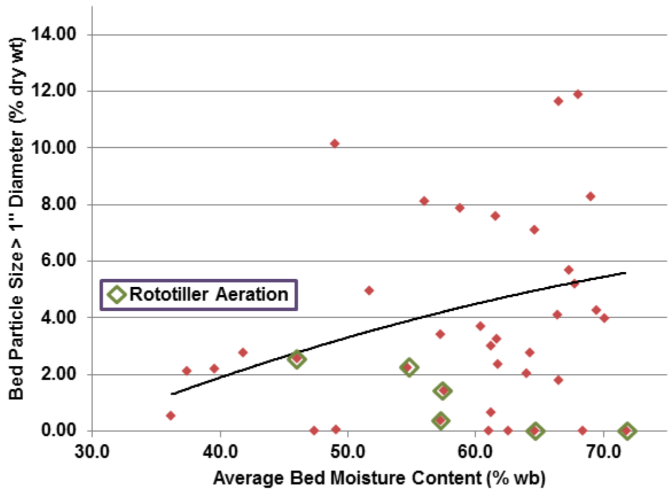

Figure 10. Effects of bed moisture content on bed particle size

Previous Housing and Important Influences on Building Design

Pasture was the most frequent form of housing producers used before transitioning to a CBP (n = 16), as shown in Table 11. Pasture was followed by freestall systems (n = 13) and a combination of freestalls and pasture access (n = 6).

Table 11. Previous housing

Type	Producer Responses
Pasture	16
Freestalls	12
Freestalls and pasture	6
Pasture and bedded pack	4
Freestalls and bedded pack	1

Twenty-one producers reported that touring other CPBs or speaking with existing CBP managers was an important influence on their choice of structure. Producers also reported that they created their own plans (n = 8) or used university plans and diagrams (n = 6) as a template for the barn's structure. These influences are shown in Table 12.

Table 12. Influences on building design

Influence	Producer Responses
Touring other barns or speaking with existing CBP managers	21
Created own plans	8
University plans and diagrams	6
Industry professionals	4
Freestall plans and design	3
NRCS	2

Barn Cleaning Practices

Barns were cleaned 1.7 times per year (n = 30). The average pack depth at cleanout was 34 inches (n = 22). The depth of material left after cleanout ranged from 0 to 18 inches, with an average of 3.1 inches (n = 30). On average, producers added 9.9 inches (n = 35) of shavings to begin the new pack, but the depth ranged from 1.4 to 48 inches.

Parlor Design

The average frequency of milking was 2.1 times per day (n = 42). Producers used a wide array of parlors, ranging from a flat barn to a rapid exit, with a herringbone being the most used parlor type (n = 22).

Milking Procedures

The frequency of milking procedures used by producers in the study is shown in Table 13. This emphasizes the importance of proper milking procedures when operating a CBP to ensure optimal udder health.

Table 13. Milking procedures

Procedure	Producer Responses
Post-dip	42
Dry treat all quarters	42
Dry teats before attach milker	41
Pre-Dip	41
Analyze milking system annually	36
Individual towels for cows	34
Use gloves in parlor	31
Automatic takeoffs	25
Culture mastitic cows	18
Milking procedure posted in parlor	5

Herd Management

Producers were asked about their preferences and methods of herd management. Their responses are detailed in Table 14.

Table 14. Herd management

Feed	Producers (%)
Total mixed ration (TMR)	36
Component feeding	12
Combination of TMR and component	2
Tail treatment	
No docking	76
Some tails docked	10
All tails docked	15
Hoof strategies	
Hooves trimmed	35
Hoof issues treated in parlor	29
Foot baths	23
Pasture time	
Summer	20
Winter	17
Dry off	
All quarters dry treated	85
Used Orbeseal®	41
Used environmental mastitis vaccine such as J-5 Bacterin™ (n = 9), J-VAC® (n = 4), or Endovac-Bovi® (n = 7)	49

Barn Structure and Layout

Structural and layout dimensions were measured for each CBP, including pack space, roof pitch and detail of the ridge opening, construction materials, eave height, and location and dimension of feed troughs and waterers. Building orientation and location of nearby structures were also documented. Published dairy barn recommendations are indicated in tables and figures for reference.

Barn and Compost Area Dimensions

The CBP dimensions (including pack and concrete areas) for 46 barns are shown in Figure 11. The average length was 157 feet, and the average width was 73 feet. The most frequent barn length was between 100 and 200 feet (60%, n = 28). The most frequent barn width was between 25 and 50 feet (30%, n = 14) with 50- to 75-feet-wide barns also occurring 30% (n = 14) of the time. Many of these barns had feed alleys and driveways in the barn. The dimensions of the pack area (excluding the feed and concrete areas) are summarized in Figure 12. The pack-length distribution is nearly the same as total barn-length dimension. The pack width is considerably different from the barn width because of the inclusion of feed and drive-through alleys. Nearly two thirds of the packs were between 25 and 50 feet wide (63%, n = 29) with about one quarter of the packs between 50 and 75 feet wide (24%, n = 11).

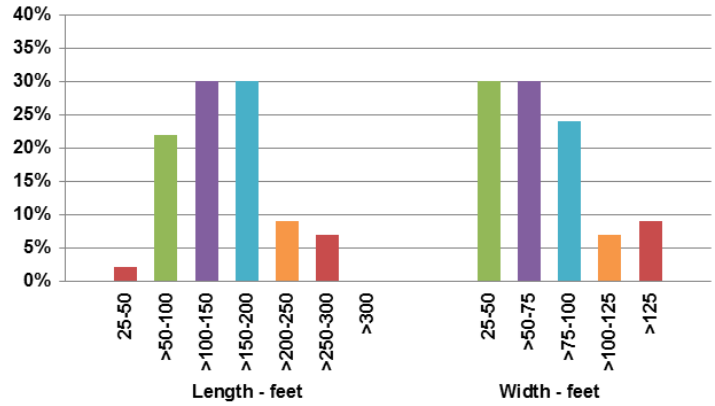

Figure 11. Dimensions of CPBs (n = 46)

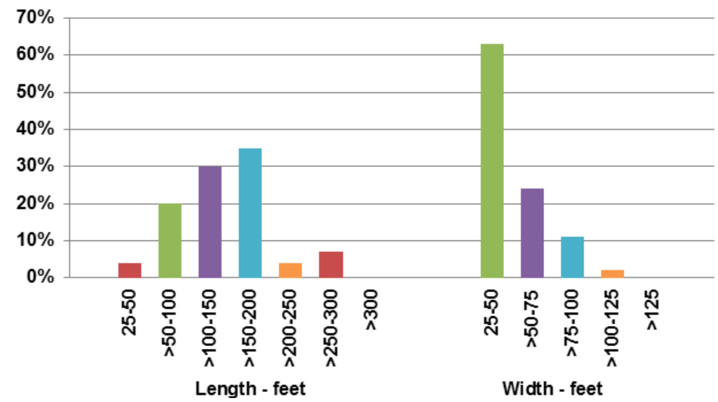

Figure 12. Dimensions of bedded pack resting area (n = 46)

Sidewall Eave Height

The CBP sidewall eave height is important to achieve a clearance that does not limit machinery access for bed cleanout, bedding distribution, and bed stirring. Natural ventilation for cow comfort during heat stress periods can be limited if the sidewall height is too small. An unobstructed sidewall would have an opening equal to the eave height. But the effective sidewall opening may be less if there is any solid fence or retaining wall. A 12-feet sidewall opening is recommended for barns less than 40 feet wide, and a 14-feet opening height is recommended for barns wider than 40 feet. Sidewall eave heights for the barns in this study are presented in Figure 13. No barn in the study was less than 40 feet wide, so the minimum recommended sidewall opening height of all barns assessed would need to be 14 feet if there is no solid fence or retaining wall. Only one third (n = 16) of the barns met that design criterion without considering whether there are retaining walls present.

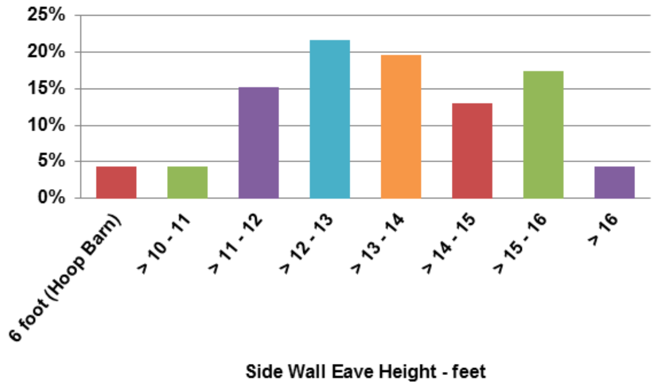

Figure 13. Sidewall eave height (n = 42)

Orientation

Barn orientation is important to limit sunlight exposure and maximize natural ventilation. The east-west orientation minimizes sunlight penetration. From a natural ventilation perspective, barns are ideally oriented so the prevailing summer winds are between 45° to perpendicular to the barn ridge. Barns oriented in this fashion will be better ventilated than a barn oriented otherwise (with all other factors the same). Barns are generally placed in an east-west orientation in Kentucky, although the recommended orientation is site-specific based upon natural wind flows. The typical prevailing winds in Kentucky come from the southwest in the summer and from the northwest in the winter, which would suggest that an east-west ridge orientation is the most effective. The orientations of visited CBPs in Kentucky are listed in Figure 14. Results show that the most frequent orientation is northeast-southwest (NE-SW, 43%, n = 20) and the next highest is east-west (E-W, 28%, n = 13).

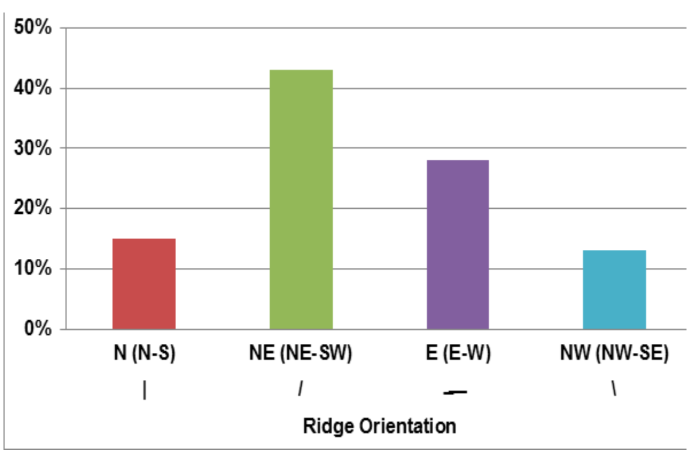

Figure 14. Ridge orientation (n = 46)

Roof Pitch

The roof pitch affects natural ventilation. A relatively flat roof on a wide barn limits the natural ventilation rate and makes it easier for pockets of warm moist air to become trapped. That condition becomes critical when warm moist air is trapped against cold roof surfaces during winter weather conditions. Figure 15 illustrates the roof pitches for the study barns. There are 48 measurements because two barns were found to have different pitches on each side of the ridge. Over half of the barns had a 4:12 pitch (58%, n = 28), while nearly one third had pitches between 3:12 and 3½:12 (29%, n = 14). Barns with roof pitches of less than 4:12 (33%, n = 16) would limit the natural ventilation rate per cow.

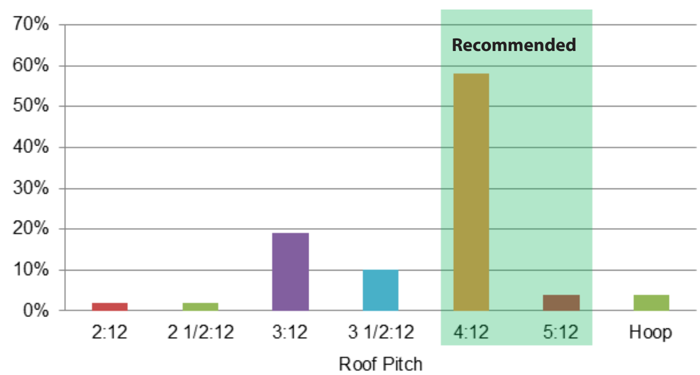

Figure 15. Roof pitch (n = 48)

Ridge Design

Figure 16A illustrates five ridge designs that were categorized. Ridge design affects air movement and removal of warm moist air that collects under the roof. The design of the ridge can help or inhibit barn ventilation depending on the wind velocity and direction relative to the ridge line. The open ridge and the open ridge with a cover are not nearly as sensitive to wind direction as the overshot ridge. For example, the wind moving from right to left in the pictured overshot roof in Figure 16A would block or reduce removal of hot, moist air under the roof. Characteristics of the CBP ridge are shown in Figure 16B. The primary types of barn ridge found in the CBP study were overshot ridges (52%, n = 24), open ridge with cover (24%, n = 11), capped ridge (15%, n = 7), open ridge (4%, n = 2) and hoop structure (4%, n = 2).

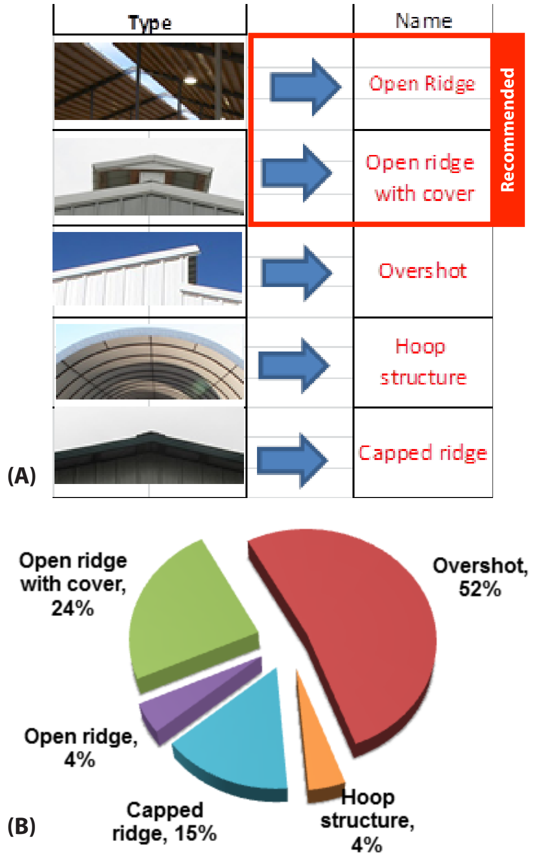

Figure 16. Roof ridge types (n = 46)

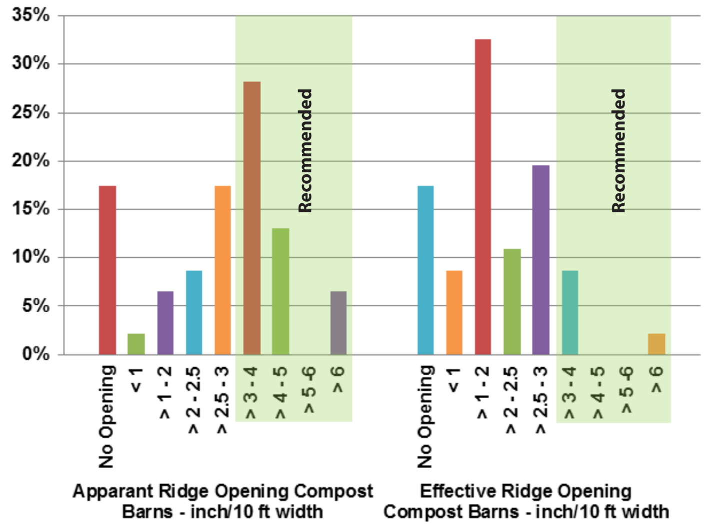

Figure 17. Ridge opening to barn width ratio (n = 46)

Continuous Ridge Opening

The width of the continuous ridge opening controls air exhausting from the barn. As the width of a barn increases, the ridge opening should also increase. Figure 17 summarizes the ratio of ridge opening to barn width on the CBPs visited in Kentucky. Figure 17 notes the present recommended minimum ridge opening width of 3 inches per 10 foot of barn width with a minimum width requirement of 12 inches for barns of less than 40 feet in width. Two ridge opening values are shown in Figure 17: (1) apparent ridge opening (1 in./10 ft.. of building width) and (2) effective ridge opening (1 in./10 ft. of building width). The apparent opening is the ridge opening width as seen from inside the barn. The effective opening is the smallest width through which air flows to the outside of the barn at the ridge. The effective ridge opening is the dimension X in Figure 18. For the open ridge, the apparent and the effective ridge opening are equal. For an open ridge with cover, the dimension of the opening between the roof sheet and the cap/cover sheet is the effective ridge opening if it is less than 75 percent of the apparent ridge opening, X. If larger than 75 percent, the effective ridge opening is the apparent ridge opening. For an overshot ridge opening, the effective ridge opening (X dimension) is measured at the roof opening, which is the distance between top edge of the lower roof member and the underside of the top roof member, or overshot roof component.

Figure 17 indicates the compost barn ridge measurements as a ratio of the ridge opening to barn width (1 in./10 ft.). Eighteen percent (n = 8) of the barns had no ridge opening. Based on the apparent ridge opening, 18 percent (n = 8) had inadequate ridge opening (< 2.5 inch/10 ft.), while 18 percent (n = 8) had marginal ridge openings (> 2.5 to < 3 inch/10 foot), and 48 percent (n = 22) equaled or exceeded the recommended ridge opening. However, based on the effective ridge opening, 53 percent (n = 32) had inadequate ridge opening as defined above, and 20 percent (n = 9) had marginal ridge openings, and only 11% (n = 5) equaled or exceeded the recommended ridge opening. The large majority of barns had ridge opening restrictions that could cause inadequate natural ventilation, significantly affecting cows. An adequate rigid opening is important for winter natural ventilation. The rigid opening is important during summer to remove heat and moisture trapped under the roof. The primary summer ventilation is natural cross-ventilation caused by winds, and the ridge ventilation is secondary. But under calm summer winds (< 2 mph), particularly under heat stress conditions, the ridge vent becomes very important because it is the only avenue for heat to exit the barn.

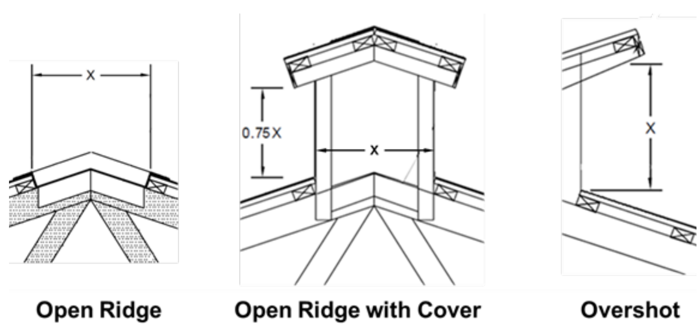

Figure 18. Effective ridge opening dimension for ridge with cover and overshot (*Ridge Openings for Naturally Ventilated Dairy Shelters*, McFarland, Graves, Tyson, Wilson. DIP 811, Penn State University, 2007).

Waterers

A cow's water intake regulates her dry matter feed intake and, consequently, has a critical effect on her milk production. Thus, a cow should have unlimited access to water at all times, including sufficient available waterer space so that a cow is not limited in meeting her needs. The free access water trough length or waterer openings of visited CBPs are shown in Figure 19. Only 15 percent meet recommendations of 3½ to 5¼ inches per cow, or 10 to 15 cows per waterer opening (McFarland, Graves, Tyson, Wilson. DIP 811, Penn State Cooperative Extension, 2007). In nearly one quarter of the CBPs (22%, n = 10), cows did not have access to water at the barn. Cows in over 75 percent (n = 36) of the barns were short of waterer spaces in the barn, which could limit their milk production.

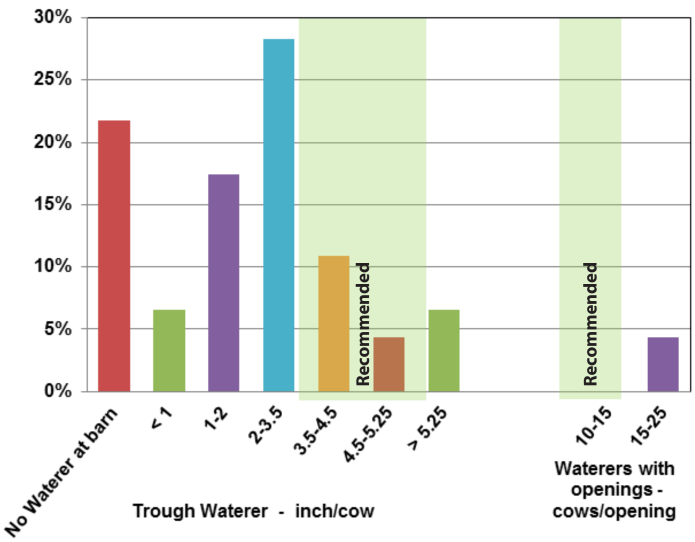

Figure 19. Waterer space (n = 46)

Feedbunks

Cow dry matter intake correlates to milk production. Adequate feed bunk space helps ensure that the cows' feed intake is not limited. Figure 20 summarizes the feedbunk space found at the CBPs. The recommended space is two to three feet per cow (McFarland, Graves, Tyson, and Wilson. DIP 811, Penn State Cooperative Extension, 2007). About 22 percent (n = 10) of the CBPs met this recommendation and an additional 9 percent (n = 4) exceeded it. There were no feedbunks at 46 percent (n = 21) of the CBPs, although most of those barns had concrete alleyways leading to nearby feedbunks. Inadequate bunk space was found at 24 percent (n = 11) of the barns.

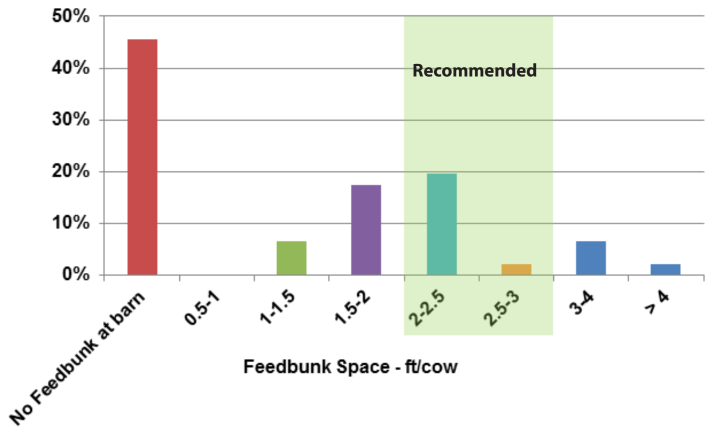

Figure 20. Feedbunk space (n = 46)

Ventilation/Circulation System

The primary method for air movement in each CBPs visited was determined. The type of ventilation/circulation system is listed in Figure 21. All the barn structures were naturally ventilated. Air movement within barns was supplemented by mechanical methods in most of the structures. The majority of CBPs used box fans (45%, n = 21), 32 percent (n = 15) had no mechanical method for air ventilation/circulation, and 23 percent (n = 11) were using high volume low speed fans (HVLS).

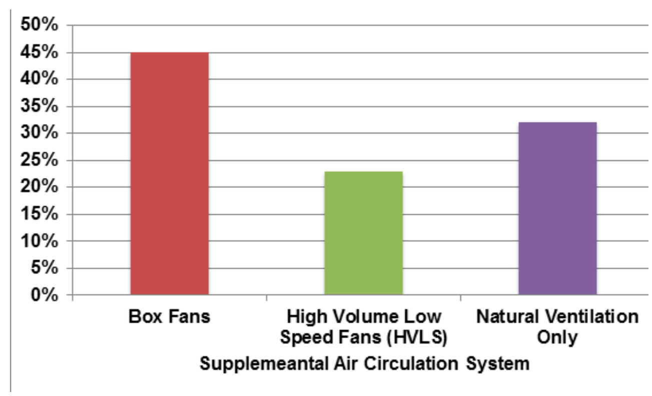

Figure 21. Type of supplemental air circulation (n = 47)

Lighting

Lighting in CBPs was noted at each dairy visited. The summary of these observations is presented in Figure 22. Most CBPs did not have lights (34%, n = 16). High intensity discharge (HID) was the most frequent form of lighting producers used (26%, n = 12), followed by fluorescent (15%, n = 7), incandescent (15%, n = 7), and compact fluorescent (11%, n = 5).

The average light power (W/sq. ft.) used in a barn depended on the type of bulb in use. Table 15 gives the average and range found for each type of lighting. Incandescent bulbs had the highest wattage per square foot (0.129 W/sq. ft.), followed by high intensity discharge bulbs (0.084 W/sq. ft.), fluorescent bulbs (0.079 W/sq. ft.), and compact fluorescent bulbs (0.014 W/sq. ft.).

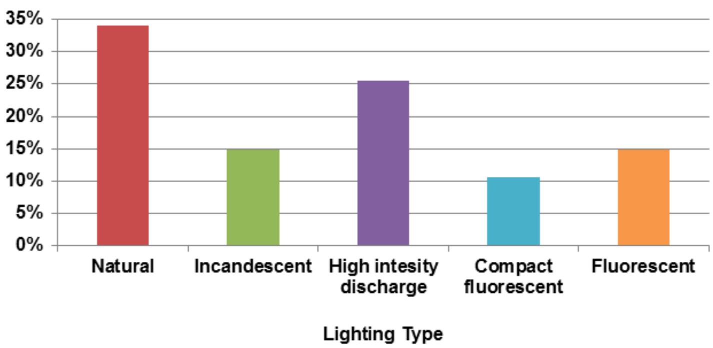

Figure 22. Lighting (n = 47)

Table 15. Average light power (W/sq. ft.)

Bulb	Mean	Range
Incandescent	0.129	0.054 to 0.275
High intensity discharge	0.084	0.018 to 0.232
Fluorescent	0.079	0.048 to 0.087
Compact fluorescent	0.014	0.006 to 0.030

References

Stowell et al., 1998

McFarland, Graves, Tyson, Wilson. Ridge Openings for Naturally Ventilated Dairy Shelters. DIP 811, Penn State University, 2007.

Acknowledgments

We would like to thank the following groups and individuals for their help with this study: Kentucky dairy producers who participated in the study, University of Kentucky Department of Animal and Food Sciences, University of Kentucky Department of Biosystems and Agricultural Engineering, Dr. Melissa Newman, Kabby Akers, University of Kentucky Regulatory Services, county agricultural extension agents, Kentucky Dairy Development Council, Dairy Records Management Systems, Dairy Farmers of America, Inc. (Southeast Area), Maryland Virginia Milk Producers Cooperative Association, Inc., Lone Star Milk Producers, Inc., Prairie Farms, Inc., Organic Valley Family of Farms, Dean Dairy, and Purity Dairies.